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# Internalization of airport congestion

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**Abstract**

This paper analyzes the internalization of airport congestion by nonatomistic carriers. It is shown that, in allocating traffic between the peak and off-peak periods, a monopolist fully accounts for the effect of congestion on passenger time costs, while also taking account of its impact on his own operating costs. The analysis thus suggests no role for congestion pricing under monopoly conditions. In an oligopoly setting, carriers are shown to internalize only the congestion they impose on themselves. A congestion toll that captures the uninternalized portion of external costs can then improve the allocation of traffic 

## 1. Introduction

Air traffic delays have grown dramatically in the US over the last few years, and delays have plagued airline traffic in Europe for an even longer period. On both sides of the Atlantic, delays are now a major public policy issue. Total US delays, measured by the number of flights arriving more than 15 minutes late, grew from 374,116 in 1999 to 450,289 in the year 2000, for a stunning 20.4% single-year increase. So far in 2001, US delays are running below the 2000 rate.

Table 1 shows the total number of delays, as well as on-time performance, at the 15 US airports with the most delays in 1999. The delay totals represent delays attributable to local operations at the given airport, while the on-time figures also capture the effect on local flights of delays elsewhere in the system. Table 1 shows the poor on-time records of Newark and New York-La Guardia, which are well known, but it also reveals similar problems at other airports, such as Boston, Philadelphia, and Washington-Dulles.

Although weather is the major source of delays, accounting for well over half of the total in most cases, Table 1 shows that the second largest source is "volume" (traffic exceeding airport capacity). However, because airports restrict operations during bad weather, both sources actually reflect the same imbalance between flights and airport capacity.[2]

Solutions to the delay problem are now widely discussed. One remedy is to increase the size of congested airports by investing in new runways. However, the long gestation period of such investment projects means that the benefits lie far in the future. Improvements in air traffic control, which are slowly being implemented, can reduce delays by increasing the capacity of the nation's airspace while also allowing busy airports to handle more flights. A third remedy for the delay problem is the imposition of congestion pricing at US airports. Under such a system, the landing fees paid by airlines (which currently depend only on aircraft weight) would vary with the level of congestion at the airport. Operating costs at peak hours would then rise substantially compared to off-peak costs, leading to a redistribution of traffic as airlines shift some flights away from the peak. The result would be a decline in airport congestion, reducing the number of delays. So far, no US airport has implemented congestion pricing, but endorsements of such a system are now frequently heard. For example, the influential monograph by the Transportation Research Board (1999) called for imposition of congestion pricing.

The theory of congestion pricing has been developed mainly as a response to the problem of road congestion (see Small (1992) for a survey). The theory shows that

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[1] I thank Ami Glazer for helpful comments. Any shortcomings in the paper, however, are my responsibility.

[2] Weather conditions far from an airport can also create delays by blocking air-traffic corridors, reducing the capacity of the air space.

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Table 1
Delays in 1999 at most conyested US airports[a]

| Airport | Delays | % Weather | % Volume | Percent on time | | Carrier and % flight share | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Arrival | Departure | 1st Carrier | 2nd Carrier | 3rd Carrier |
| Chicago-O'Hare | 49,202 | 73.8 | 12.7 | 66.4 | 70.1 | United (44.5) | American (38.9) | Northwest (2.2) |
| Newark | 36,553 | 76.4 | 9.1 | 61.6 | 69.0 | Continental (57.2) | United (7.9) | Delta (5.7) |
| Atlanta | 32,737 | 79.8 | 9.4 | 69.1 | 73.2 | Delta (73.5) | Air Tran (10.9) | US Airways (2.3) |
| NY-La Guardia | 28,474 | 56.1 | 13.0 | 59.9 | 71.1 | US Airways (37.6) | Delta (18.8) | American (16.8) |
| San Francisco | 21,187 | 82.5 | 8.3 | 67.9 | 78.5 | United (58.2) | American (7.4) | Delta (4.8) |
| Dallas-Ft. Worth | 16,731 | 75.5 | 15.8 | 78.3 | 76.3 | American (68.5) | Delta (17.3) | United (1.9) |
| Boston | 14,989 | 76.0 | 1.2 | 62.3 | 70.7 | US Airways (25.9) | American (25.7) | Delta (15.3) |
| Philadelphia | 14,516 | 72.6 | 6.4 | 59.6 | 62.1 | US Airways (65.8) | Delta (6.1) | American (6.0) |
| NY-Kennedy | 13,547 | 74.6 | 8.5 | 72.0 | 81.0 | American (27.8) | Delta (20.4) | TWA (15.8) |
| Phoenix | 11,919 | 35.2 | 46.2 | 70.4 | 69.2 | America West (48.4) | Southwest (26.2) | United (5.4) |
| Detroit | 11,522 | 46.1 | 21.4 | 75.4 | 73.7 | Northwest (79.8) | Delta (3.3) | Southwest (2.8) |
| Los Angeles | 10,646 | 84.5 | 1.2 | 73.9 | 79.2 | United (36.3) | American (17.2) | Southwest (11.5) |
| St. Louis | 9,631 | 85.5 | 1.3 | 78.0 | 74.1 | TWA (73.2) | Southwest (12.9) | Delta (2.5) |
| Houston | 9,524 | 84.8 | 4.8 | 71.2 | 75.4 | Continental (81.6) | Delta (3.3) | American (2.9) |
| Washington-Dulles | 9,248 | 63.9 | 17.1 | 63.6 | 70.1 | United (62.4) | US Airways (19.2) | Delta (4.4) |

[a] 1999 is the most recent year for which the data in the first three columns are available at the airport level. The figures in these columns are taken from the FAA web site (http://www.faa.gov/newsroom.htm) The on-time percentages, which pertain to July 1999, are taken from DOT's Air Travel Consumer Report (http://www.dot.gov/airconsumer/). The flight-share data are from Baker (2000).

peak usage of a road or other congested facility is excessive because any given user does not take into account the delays he imposes on fellow users. By charging a congestion toll equal to the cost of the external delays that each user generates, peak usage can be appropriately restricted.

Transportation researchers have long recognized that the principles of congestion pricing apply to airports as well as urban highways. The earliest discussions of airport congestion pricing are offered by Levine (1969) and Carlin and Park (1970), with Morrison (1983) and Morrison and Winston (1989) providing later treatments. However, Daniel (1995, 2000, 2002) presents the most sophisticated analysis, using a detailed simulation model to show the effects of congestion pricing in a realistic setting.

Given the magnitude and urgency of the airport congestion problem, it is essential that any price-based remedies are built on a sound theoretical understanding of the problem. Most of the previous literature, however, can be criticized for simply extrapolating the conclusions of road-pricing models to the airport case without recognizing a critical difference between these contexts. The difference is that road users are appropriately viewed as atomistic, with each user small relative to total traffic, but that airlines are nonatomistic. As seen in Table 1, most of the flights at the highly congested US airports are operated by one or two airlines. United and American, for example, each operate around 40% of the flights at Chicago-O'Hare, while Delta operates over 70% of Atlanta's flights. Given this pattern, an atomistic model of congestion will give incorrect conclusions when applied in an airport context.

The present paper argues that the verdict on airport congestion is softened when the atomistic model is abandoned. The paper argues that, in contrast to atomistic users of a congested facility, who ignore their external effects, a nonatomistic airline takes into account a portion of the congestion caused by each of its flights. Specifically, the airline *internalizes the congestion each flight imposes on the other flights it operates*. In light of this internaliźation, the over-allocation of flights to peak hours may not be as severe in practice as an atomistic model would predict. The paper thus suggests that congestion pricing may have a more-limited role than the one envisioned by many analysts. In the paper, these arguments are developed in a nontechnical fashion, paralleling the formal economic analysis presented by Brueckner (2002) in a companion paper.

Since Daniel (1995) recognizes the possible internalization of airport congestion, the basic insight of the paper has appeared before in the literature. However, the underlying analysis presented by Brueckner (2002) is more transparent than that offered by Daniel, who relies on a complex simulation model. In addition, airlines in Brueckner's model internalize the congestion costs experienced by passengers through an effect on airfares (because of lower willingness-to-pay by passengers, fares must be cut during congested times). By contrast, demand conditions are suppressed in Daniel's model, with airlines behaving simply as cost-minimizers.[3]

[3] Daniel assumes that airlines allocate their flights so as to minimize operating costs plus passenger time costs. While this is a convenient behavioral assumption, time costs are in actuality not a direct cost to the airline.

The plan of the paper is as follows. Section 2 develops the standard, atomistic model of congestion pricing, focusing for concreteness on the road context. Drawing on the analysis of Brueckner (2002), Section 3 presents the analysis of airport congestion, developing the conclusions regarding internalization.

## 2. The atomistic model: an analysis of road congestion

To understand the internalization of congestion by airlines, it is useful to first review the standard model, where the agents causing congestion are atomistic. To this end, consider use of a roadway, which connects a suburb to the downtown area of a city. Let the day be divided into two travel periods, differentiated by the level of congestion on the roadway. The peak period, which corresponds to the morning and evening rush hour, is congested, while congestion is absent during the off-peak period, which captures the remainder of the day. Congestion during the peak period means that the speed of traffic is low, implying that the time cost incurred by each road user in accessing the city center is correspondingly high. By contrast, traffic in the uncongested off-peak period moves at the free-flow speed, leading to a low time cost.

Under congested conditions, each user of the road imposes an external cost on the other users. This cost arises because the presence of the extra user leads to a slight reduction in traffic speed, and a corresponding increase in time costs for each of the other travelers. Summing these extra time costs across the other individuals yields the external cost, denoted $X$. Because each road user slows everyone else down, external costs are generated symmetrically, with each and every user imposing costs equal to $X$ on his fellow travelers. Given that individual road users are small relative to total traffic and do not coordinate their travel decisions, they are appropriately viewed as atomistic.

To find the equilibrium division of traffic between the peak and off-peak, the benefits from travel in the two periods must be considered, recognizing that these benefits differ across individuals. For example, peak travel benefits will be high relative to off-peak benefits for downtown commuters with inflexible work schedules (who would need to change jobs to travel in the off-peak). On the other hand, individuals who travel to the city center for shopping or other leisure activities may receive little benefit from peak travel, preferring the off-peak instead (shops, for example, may open only after the morning peak is past). For other individuals, including those with flexible work schedules, the benefits from peak and off-peak travel may be similar in magnitude.

Time costs also matter in the choice between the peak and off-peak periods. In particular, individuals will base their decision on the *net benefit of travel*, which equals (gross) travel benefit minus time costs.[4] Since the peak yields low gross benefits for shoppers along with high time costs, net benefits for this group will be higher in the off-peak period. Conversely, for commuters with inflexible work hours, net benefits will be higher in the peak even though time costs are substantial. Members of an intermediate group, for whom (gross) benefits are not much larger in the peak than the off-peak, must make a finer calculation in deciding when to travel. As long as net travel benefit is higher in the peak, additional members of this group will join the peak period. But as additional travelers enter the peak, congestion and time costs rise, depressing the net benefit of peak travel.[5] The equilibrium traffic allocation is reached when no additional member of the intermediate group wishes to join the peak period. A particular group member, denoted the *marginal* traveler, is then indifferent between peak and off-peak travel. For this marginal individual, net travel benefits are equal between the peak and off-peak periods.

The resulting allocation of traffic between the periods satisfies travelers in that no one wishes to alter the timing of his trip. But the allocation is not socially desirable. The reason is that, in deciding between the periods, none of the peak travelers considers the external costs generated by his presence on the road. Because external costs are ignored, too many travelers use the peak period relative to what is socially desirable. Thus, the *socially optimal allocation* of traffic has fewer travelers in the peak, and more in the off-peak, than the equilibrium allocation.

This conclusion can be understood by focusing on the net *social* benefit of travel, which equals the net *private* benefit for an individual (gross benefit minus time cost, from above) *minus the external costs* generated by his presence on the road. Because external costs $X$ are subtracted, the net social benefit of peak travel is *less than* the net private benefit, while the two net benefits coincide in the off-peak period (where $X$ is zero).

From society's point of view, an additional traveler should be allocated to the peak period as long as the net social benefit of travel for this individual is larger in the peak. When this relationship holds, the individual gain from peak travel, minus the external cost imposed on others, exceeds the gain from off-peak

[4] Since out-of-pocket costs such as payments for gasoline will be approximately the same across periods, they can be ignored.

[5] Along with this rise in congestion, the added individuals will have lower gross benefits from peak travel and higher off-peak benefits (for example, their work-hour flexibility may be higher).

travel, meaning that use of the peak is socially desirable for this individual. As additional travelers are added to the peak, congestion rises, reducing the net social benefit of peak travel. Eventually, net social benefits become equal between the two periods for the next potential peak traveler, and only then is society indifferent as to whether this individual is added to the peak. When this social optimality condition is satisfied, the aggregate net benefits of travel (total gross benefits minus total time costs) are as high as possible.

Given this discussion, the undesirability of the equilibrium traffic allocation is clear. Recall that, in the equilibrium, net *private* benefits are equal between the peak and off-peak periods for the marginal traveler. But because net private benefit in the peak does not include the external cost $X$, it follows that *the net social benefit of peak travel is less than the net social benefit of off-peak travel* for the marginal traveler. As a result, social welfare would rise if the marginal traveler, along with a group of similar individuals, were shifted from the peak to the off-peak period (aggregate net travel benefits would increase).

The inefficiency of the equilibrium is caused by the failure of road users to consider the external costs of the congestion they create. This failure can be corrected if the government levies a monetary charge that explicitly captures the external costs. The charge, referred to as a "congestion toll", is set equal to X, the value of external costs imposed by each traveler. Because $X$ is sensitive to traffic flows, the ideal toll system is volume sensitive, capable of adjusting the toll as conditions change. The system thus generates a zero toll in the off-peak period, when $X$ is zero, and a positive toll during the peak, whose magnitude depends on the exact volume of peak traffic.

With the peak toll capturing external costs, the marginal traveler in the old equilibrium, who was previously indifferent between peak and off-peak travel, now finds that the peak is too expensive. This individual, along with others similar to him, switches to off-peak travel, and in the new equilibrium, a new marginal traveler emerges. For this individual, net private benefits, *modified by subtraction of the peak toll*, are equated between periods. But since the toll exactly captures external costs, net *social* benefits are equated between periods for the new marginal individual. As a result, the new equilibrium coincides with the socially optimal traffic allocation.

## 3. An analysis of airport congestion

To analyze airport congestion, many of the elements of the simple model of road congestion can be borrowed. First, just as the road model focused on a single roadway, abstracting from network considerations, the analysis of airport congestion can focus on a single airport. While any given airport is part of a large airline route network, this simplification is logically defensible if congestion is present only at the airport under consideration, with all other airports uncongested. This assumption is unrealistic, but it simplifies the analysis. The effect of introducing network considerations, where congestion is present at multiple airports, is discussed below.

Again borrowing from the road congestion model, the analysis distinguishes between two travel periods: a congested peak, corresponding to early morning and late afternoon hours, and an uncongested off-peak, comprising the rest of the day. Travelers are again differentiated by the magnitudes of peak and off-peak benefits. For business passengers, off-peak travel generates low benefits because it disrupts the work day. By contrast, peak travel allows an early arrival and late departure at the work destination, and generates high travel benefits. Since the timing of travel is less important for leisure passengers, peak and off-peak benefits may be similar in magnitude for this group.

As in the road congestion model, airport congestion imposes time costs on passengers. These time costs again depend on traffic volume during the peak period, which is now measured by the number of peak airline flights. Flight volume, in turn, is proportional to the number of peak passengers, assuming a single, fixed aircraft size and uniform load factors.

In contrast to the earlier model, where vehicle operating costs were viewed as independent of the level of road congestion, airline operating costs are affected by congestion in an important way. By prolonging flights, airport congestion reduces daily hours of aircraft utilization, raising costs per unit of capacity. In addition, longer flights lead to higher crew costs and raise fuel expenses when delays prolong time spent in the air.

Another key difference relative to the road congestion model is that, rather than driving their own cars, individuals purchase travel services from the airline, paying an explicit fare. As will be seen, fares pay a crucial role in the analysis.

### 3.1. The monopoly case

To begin the analysis, consider a situation where the airport is entirely dominated by a monopoly carrier. Although no carrier at any major airport controls 100% of the traffic, the monopoly case approximates the situation at many dominated hubs. Because the monopoly carrier has complete market power, it can set fares at the airport as it chooses. The carrier will then determine two fares: one for peak travel and another for off-peak travel. In reality, each destination city served by the airline will have its own peak and off-peak fares, but this variety can be collapsed for purposes of the analysis. In effect, all endpoints served from the given airport are viewed as identical.

For any combination of peak and off-peak fares, individuals divide between the two travel periods by again considering net travel benefits, which are now computed taking fares into account. Net travel benefit for an individual is now equal to gross benefit minus time cost *minus the fare paid*. Individuals compare the resulting net benefits for the peak and off-peak periods, and choose the travel period yielding the larger value.

By setting fares appropriately, the monopoly airline can control the division of passengers between the peak and off-peak periods. Reducing the peak fare, for example, encourages travel in the peak period, while raising the fare discourages it. Given its ability to control traffic through fares, the monopoly airline can be portrayed as choosing the division of traffic between the peak and off-peak periods so as to maximize its profit, recognizing that fares must adjust appropriately. As shown in Brueckner (2002), the off-peak fare can be viewed as fixed in this process, being set at a level that makes the individual with the lowest off-peak benefits indifferent between traveling and not traveling. Therefore, the peak fare does all the adjusting as the monopolist varies the allocation of traffic between the periods.

Consider now the monopoly airline's calculations in deciding whether to shift some traffic to the peak period. If the airline decides to move a flight from the off-peak to the peak period, it earns more revenue because the higher peak fare can be charged in place of the lower off-peak fare that passengers on this flight previously paid. But in order to induce these previously marginal passengers to switch to the peak in the first place, the peak fare must be cut slightly below its previous value, lowering the revenue gain that is achieved. The fare must be cut by just the right amount to keep the planeload of marginal passengers indifferent between the peak and off-peak periods. Since peak time costs are rising because of the extra congestion caused by the additional flight, the fare must be cut by an amount *just sufficient to cancel the higher time costs*.

In addition to this required fare reduction, which affects all peak passengers, the airline experiences another negative effect in shifting a flight to the peak period. This effect consists of *the increase in operating costs for all the existing peak flights*, a consequence of the higher congestion caused by the added flight.

The airline's profit will be as high as possible when the gains and losses from shifting a flight to the peak exactly cancel, leaving profit unchanged. For this cancellation to occur, the revenue gain from charging the higher peak fare to previous off-peak passengers must equal the loss from higher passenger time costs (captured by the required peak fare reduction) plus the loss from higher operating costs for existing peak flights.

It can be demonstrated that, when this equilibrium condition is satisfied, the allocation of traffic between the peak and off-peak periods is socially optimal. Thus, in maximizing profit, the monopoly airline picks the allocation of traffic that is correct from society's point of view.[6] This conclusion is already partly clear from above, given that the monopolist takes account of the effects of congestion on passenger time costs and its own operating costs. The last step is to note that the difference between the peak and off-peak fares, which generates the above revenue effect, exactly mirrors the difference in travel benefits, less time costs, between the two periods.[7] As result, satisfaction of the equilibrium condition means that individual travel benefits minus time costs, *net of the external cost of congestion*, are equated between the peak and off-peak periods. As seen in the analysis of road congestion, satisfaction of this condition guarantees that the allocation of traffic between the periods is socially optimal.

Thus, unlike atomistic road users, the monopoly airline *internalizes* the cost of congestion. In the case of the higher operating costs caused by congestion, this conclusion comes as no surprise. In deciding whether to schedule another flight in the peak period, it is natural for the monopolist to consider the impact on operating costs for its existing peak flights. The internalization of passenger time costs, which occurs because these costs affect the peak fare, is more subtle. Because the monopolist controls the peak fare and must reduce it as higher congestion pushes up time costs, these costs are ultimately taken into account in the pursuit of profit.

The internalization of congestion by a monopoly airline yields an important conclusion regarding congestion pricing. In particular, the theory implies that *congestion tolls are unneeded at an airport dominated by a monopoly carrier*. Indeed, imposing congestion tolls in this situation would be counterproductive, leading to under-use of the peak period. Although the existing dominated hubs do not strictly conform to the monopoly case, the analysis suggests nevertheless that congestion pricing at these airports would not be helpful.

[6] Although the division of traffic between the periods is optimal, the level of fares chosen by the monopolist will be too high. For simplicity, a separate case where an additional market-power effect distorts the allocation of the traffic between the peak and off-peak periods is not considered. See Brueckner (2002) for a discussion of this effect.

[7] The reason is that, for the marginal passengers to be indifferent between the periods, the difference in fares must exactly offset the difference in travel benefits minus time costs.

### 3.2. Non-monopoly cases

In the case where the airport is served by many airlines, each of which behaves competitively, the above conclusions disappear, and results analogous to those in the road-congestion model reemerge. In this atomistic case, each airline fails to consider the increase in operating costs for its competitors when it schedules another peak flight. In addition, fares are beyond the control of individual carriers, being forced down to the point where they just cover operating costs. As a result, the congestion-related fare discounting that arises in the monopoly model does not occur, meaning that passenger time costs are not taken into account by the carriers.

Because airlines fail to internalize congestion in the competitive case, congestion tolls analogous to those in the earlier model are required to generate an optimal allocation of traffic between the peak and off-peak periods. The toll per flight should be set equal to the external cost it generates: the additional passenger time costs plus the extra airline operating costs resulting from the added congestion. The peak fare then rises to cover each airline's toll outlay, and as a result, marginal individuals find peak travel too expensive. Peak traffic then shrinks, and off-peak traffic grows, until the socially optimal allocation is reached.

As an intermediate case between the monopoly and competitive situations, consider the oligopoly case, where several large airlines serve the airport. In contrast to the competitive case, each carrier is large enough to exert market power, but each faces competition from the other carriers. The behavior of airlines in this setting is similar to that in the monopoly case. In particular, if one of the oligopoly carriers wishes to shift a flight from the off-peak to the peak period, it must accept a lower peak fare, which encourages some passengers to switch to the peak. Once again, the fare reduction must offset the increase in time cost per passenger caused by the extra peak flight. While the lower fare applies to peak passengers on *all* carriers, the revenue loss for the given carrier arises only because *its own passengers* are paying less. As a result, the carrier internalizes only the increase in time costs *experienced by its own passengers*. The increase in time costs for passengers using other carriers is ignored. Similarly, the carrier takes account of the increase in operating costs for *its own* existing peak flights when it adds a new flight to the peak. But it ignores the increase in peak operating costs for other carriers.

The upshot is that an oligopolistic carrier internalizes only a portion of the congestion created when it operates an extra peak flight. It internalizes the *increase in time costs for its own passengers and the increase in operating costs for its own flights*. Because congestion is only partially internalized, the outcome is similar to that in the road model, with too many flights allocated to the peak period.

The remedy is again to levy a congestion toll in the peak period. But the toll has a different magnitude than in the competitive case discussed above, where no congestion was internalized. Now, the toll captures the portion of external cost *that is not internalized,* being equal to the external congestion cost generated by an extra peak flight times *one minus each carrier's airport flight share*. For example, since each airline at a duopoly airport internalizes one-half of external costs, the toll in this case should equal *half* of the external cost generated by an extra peak flight. If the airport has four equal-size carriers, then each internalizes one-quarter of external costs. The toll should then be set at *three-quarters* of the external cost of an additional flight. These rules suggest that at an airport like Chicago-O'Hare, which approximates the duopoly case, United and American should each be charged a toll equal to half the external costs of a peak flight (see Table 1).

### 3.3. Extensions

Several extensions of this analysis are possible. One extension would recognize that large and small city-pair markets are served by aircraft of different sizes. Since the congestion created by a flight is largely independent of the size of the aircraft, congestion tolls should be independent of aircraft size. Tolls measured on a per passenger basis will then be higher for small than for large aircraft, and this difference will lead to a greater diversion of small aircraft out of the peak under a toll system. Small cities will then see a greater reduction of peak-period airline service than large endpoints under a system of congestion pricing.

Another extension would add network considerations to the model, recognizing that congestion exists at multiple airports. The required analysis is potentially complex because diversion of a flight out of the origin airport's peak period may mean that it now arrives at its destination during that airport's peak (the outcome depends in part on flight duration). Despite such complications, it is likely that the main lessons of the present analysis would continue to be relevant in a network setting.

## 4. Conclusion

This paper has analyzed the internalization of airport congestion by nonatomistic carriers. It has been shown that, in allocating traffic between the peak and off-peak periods, a monopolist fully accounts for the effect of congestion on passenger time costs, while also taking account of its impact on his own operating costs. The analysis thus suggests no role for congestion pricing under monopoly conditions. In an oligopoly setting, carriers are shown to internalize only the congestion they impose on themselves. A congestion toll that captures the uninternalized portion of external costs can then improve the allocation of traffic.

These findings show the flaw in a direct application of road-pricing principles to the airport setting. Instead of being charged for *all* the external costs generated by an additional peak flight, as would occur if airlines were treated like road users, the toll should reflect only the costs imposed on other carriers. At an airport like Chicago-O'Hare, this rule would imply that United and American would be charged for only about half of the congestion created by an additional flight. At a monopoly airport, the rule implies a zero toll since all congestion is internalized. Given the likelihood that some form of congestion pricing will be implemented at US airports, awareness of such these conclusions may be useful.

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